

Research on Logistics Distribution Center Location Based on Analytic Hierarchy Process (AHP)

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Abstract

Location selection of logistics distribution centers is a key decision-making issue in the field of logistics engineering and management, which directly affects logistics costs, distribution efficiency and service quality. Taking the regional logistics distribution center location of a chain retail enterprise as the research object, this paper applies the Analytic Hierarchy Process (AHP) to construct a multi-criteria decision-making model. By clarifying the location objectives and sorting out the influencing factors, an evaluation system including 4 first-level indicators (economic cost, geographical location, infrastructure, policy environment) and 13 second-level indicators is established. Weights are determined through pairwise comparison matrices aggregated by expert geometric mean, and finally three candidate location schemes are ranked and optimized. The research results show that economic cost and geographical location are the core influencing factors for logistics distribution center location, accounting for 35.2% and 28.7% of the weight respectively, and the selected optimal scheme has obvious advantages in comprehensive benefits. Sensitivity analysis verifies the robustness of the ranking result. This study provides a scientific and feasible decision-making method for enterprises' logistics distribution center location, and also offers practical references for the application of AHP in the field of logistics management.

Keywords

Analytic Hierarchy Process, Logistics Distribution Center, Location Decision, Indicator System, Weight Calculation, Sensitivity Analysis

1. Introduction

With the rapid development of the e-commerce industry and the large-scale ex-

pansion of chain retail enterprises, logistics distribution, as a key link connecting production and consumption, has become an important part of enterprises' core competitiveness in terms of efficiency and cost control. As a hub node of the logistics network, the logistics distribution center undertakes multiple functions such as cargo storage, sorting and distribution. The scientificity of its location is directly related to key performance indicators such as logistics transportation cost, distribution response speed and customer service level. According to statistics, the location decision of logistics distribution centers accounts for more than 30% of the impact on total logistics costs. Unreasonable location may lead to a series of problems such as lengthened transportation routes, overstocked inventory and delayed distribution, which seriously restrict the sustainable development of enterprises.

At present, China's logistics industry is in a stage of transformation and upgrading, and enterprises have put forward higher requirements for the scientificity and accuracy of logistics distribution center location. Traditional location methods mostly rely on empirical judgment or single cost indicator evaluation, which are difficult to balance economic, social, environmental and other factors, and easily lead to decision-making deviations. Therefore, constructing a multi-dimensional and multi-level location evaluation system and adopting scientific decision-making methods for comprehensive evaluation have become the key to solving the problem of logistics distribution center location.

As a multi-criteria decision-making tool, the Analytic Hierarchy Process has the advantage of combining qualitative and quantitative analysis, and can effectively deal with decision-making problems in complex systems. Compared with existing studies using Fuzzy AHP, AHP-TOPSIS, and other hybrid models, this study retains the standard AHP framework to improve operability for small and medium-sized retail enterprises. It supplements complete expert judgment aggregation rules, consistent data normalization methods, and sensitivity verification procedures, forming a replicable research process. This paper applies AHP to the research of logistics distribution center location, further improves the theoretical system of logistics location decision-making, enriches the application scenarios of AHP in the field of logistics engineering and management, and provides a research framework for similar multi-criteria decision-making problems.

The location evaluation system and decision-making model constructed in this paper can provide enterprises with a clear location decision-making process and scientific analysis tools, helping enterprises systematically consider various influencing factors in the location process and avoid decision-making errors caused by empiricism. Through precise location, enterprises can optimize logistics costs, improve distribution efficiency and service quality, enhance market competitiveness, and provide a reference for the rational layout of regional logistics networks to promote the sustainable development of the logistics industry.

The core research content of this paper includes:

Firstly, sorting out the main influencing factors of logistics distribution center location and constructing a scientific and reasonable location evaluation indicator

system;

Secondly, using AHP to determine the weight of each evaluation indicator and clarify the influence degree of different factors on location decisions;

Thirdly, combining specific cases to conduct comprehensive evaluation and ranking of candidate location schemes and select the optimal one;

Fourthly, conduct sensitivity analysis to verify the stability of the ranking conclusion.

The technical route of this paper is as follows:

Firstly, clarify the influencing factors of logistics distribution center location through literature research and actual investigation;

Secondly, construct a hierarchical structure model including goal layer, criterion layer and indicator layer;

Thirdly, invite experts, aggregate judgments via geometric mean, construct pairwise matrices, and test consistency;

Fourthly, collect multi-source data and convert them into unified 1–10 scores via linear normalization;

Finally, conduct comprehensive scoring and ranking and sensitivity analysis of candidate schemes and perform sensitivity analysis.

2. Relevant Theoretical Basis Ease of Use

2.1. Overview of Logistics Distribution Center Location

Logistics distribution center location refers to the process of selecting the optimal geographical location to build a logistics distribution center within a certain regional scope according to the enterprise's logistics strategic objectives, customer distribution, supply chain layout and other factors. Location decision-making needs to comprehensively consider economic, technical, social, environmental and other factors, which is a complex systematic project. Common location methods include gravity center method, linear programming method, heuristic algorithm, Analytic Hierarchy Process, etc. Among them, AHP is widely used in multi-criteria location decision-making due to its simple operation and clear logic (Wang, 2019; Li & Guo, 2020; Wang, 2021). In recent years, many scholars have combined AHP with TOPSIS, fuzzy logic, and entropy weight to improve accuracy; however, these hybrid models are relatively complex for most chain retail enterprises.

2.2. Principle and Steps of Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method proposed by American operations researcher T. L. Saaty in the 1970s (Saaty, 1988). Its core idea is to decompose complex decision-making problems into several levels, determine the relative importance of elements at each level through pairwise comparison, then calculate the weight of each element, and finally conduct comprehensive evaluation of schemes based on weights. The core steps include: hierarchical modeling, pairwise comparison matrix construction, weight

calculation, consistency test, scheme evaluation, and robustness verification.

The specific steps of AHP are as follows:

- 1) Establish a hierarchical structure model, decompose the decision-making problem into goal layer, criterion layer, indicator layer (or scheme layer);
- 2) Select experts and aggregate judgments. Construct pairwise comparison matrices to evaluate the relative importance of elements at the same level;
- 3) Calculate the weight vector, solve the maximum eigenvalue and corresponding eigenvector of the pairwise comparison matrix by the eigenvalue method, and normalize the eigenvector to obtain the weight vector;
- 4) Conduct consistency test to verify the logical consistency of the pairwise comparison matrix. If the test is passed, the weight vector is valid; if not, the pairwise comparison matrix needs to be adjusted;
- 5) Conduct comprehensive evaluation of schemes, calculate the comprehensive score of each scheme according to the weight of each indicator and the score of the scheme on each indicator, and rank and optimize the schemes;
- 6) Conduct sensitivity analysis to test the stability of the ranking.

3. Construction of Evaluation Indicator System for Logistics Distribution Center Location

3.1. Principles of Indicator System Construction

To ensure the scientificity and rationality of location evaluation, the indicator system is constructed following the following principles:

Systematic principle: Fully cover the key factors affecting logistics distribution center location and form a complete evaluation system;

Scientific principle: The indicators are clearly defined and the calculation methods are standardized, which can objectively reflect the core needs of location;

Operability principle: Indicator data are easy to obtain and convenient for quantitative or qualitative analysis;

Importance principle: Prioritize indicators with significant impact on location decisions and avoid redundancy;

Compatibility principle: Balance economic, social, environmental and other needs to maximize comprehensive benefits.

3.2. Establishment of Hierarchical Structure Model

According to the principle of AHP and combined with the actual needs of logistics distribution center location, the following hierarchical structure model is constructed:

- Goal layer (A): Optimal location scheme of logistics distribution center.
- Criterion layer (B): Economic cost (B1), geographical location (B2), infrastructure (B3), policy environment (B4).
- Indicator layer (C):
 - Economic cost (B1): Land cost (C1), construction cost (C2), transportation cost (C3), operation cost (C4);
 - Geographical location (B2): Distance from suppliers (C5), distance from cus-

tomers groups (C6), regional traffic convenience (C7);

Infrastructure (B3): Transportation infrastructure (C8), warehousing facility supporting (C9), information infrastructure (C10);

Policy environment (B4): Land policy (C11), tax incentives (C12), industrial support policies (C13).

3.3. Indicator Explanation

Indicator explanation:

Land cost (C1): The land purchase or lease cost of the location area, which directly affects the initial investment of the project;

Construction cost (C2): The construction, equipment purchase and other related costs of the distribution center;

Transportation cost (C3): The transportation expenses of goods entering and leaving the distribution center, which are closely related to transportation distance and mode;

Operation cost (C4): The labor, water and electricity, warehousing management and other expenses in the daily operation of the distribution center;

Distance from suppliers (C5): The straight-line or transportation distance between the distribution center and main suppliers, affecting procurement efficiency and cost;

Distance from customer groups (C6): The distance between the distribution center and the concentrated area of target customer groups, affecting distribution response speed;

Regional traffic convenience (C7): The perfection of the road, railway, aviation and other transportation networks in the location area;

Transportation infrastructure (C8): The road grade, transportation hub distribution and other conditions around the location area;

Warehousing facility supporting (C9): The existing warehousing resources, loading and unloading equipment and other supporting conditions in the location area;

Information infrastructure (C10): The network coverage, data transmission capacity and other information support conditions in the location area;

Land policy (C11): The relevant local government policies on land use, such as preferential land transfer prices and service life;

Tax incentives (C12): The tax reduction, exemption and return preferential policies for logistics enterprises issued by local governments;

Industrial support policies (C13): The capital support, talent introduction and other relevant policies for the logistics industry issued by local governments.

4. Application of Location Decision-Making Model Based on Analytic Hierarchy Process

A chain retail enterprise plans to build a regional logistics distribution center in a

province, responsible for cargo distribution to more than 200 stores in the province and surrounding areas. After preliminary screening, three candidate location schemes are determined:

- Scheme 1: Urban industrial park. Complete infrastructure, convenient transportation, moderate land cost and policy incentives, covering core urban areas.
- Scheme 2: County logistics park. Low land and construction costs, weak transportation and information infrastructure, strong tax and industrial support, mainly serving counties and rural areas.
- Scheme 3: Near a prefecture-level city transportation hub. Balanced cost, superior geographic location, complete transportation and warehousing infrastructure, full coverage of 200+ stores, and convenient multi-modal transportation.

This paper uses AHP to comprehensively evaluate the three schemes and select the optimal one (Liu & Wang, 2022; Chen, 2020).

4.1. Expert Selection and Judgment Aggregation

Ten experts were selected:

6 academic experts in logistics management with ≥ 8 years of research experience.

4 enterprise logistics directors with ≥ 10 years of distribution network planning experience.

Individual judgment matrices were aggregated using the geometric mean to form group pairwise comparison matrices, reducing subjective deviation and improving stability.

The 10 experts were selected according to professional qualifications and practical experience: 6 senior scholars in logistics management with more than 8 years of research experience, and 4 logistics directors of chain retail enterprises with more than 10 years of practical experience in distribution network planning. Individual judgment matrices from each expert were aggregated using the geometric mean to form the final group pairwise comparison matrices, which reduces subjective deviation and improves the stability of the evaluation results.

According to the hierarchical structure model, 10 experts in the field of logistics management and enterprise managers are invited to conduct pairwise comparison of elements at the same level using the 1 - 9 scale method to construct pairwise comparison matrices. The meaning of the 1 - 9 scale method is: 1 means two elements are equally important, 3 means the former is slightly more important than the latter, 5 means the former is more important than the latter, 7 means the former is much more important than the latter, 9 means the former is extremely more important than the latter; 2, 4, 6, 8 are the intermediate values of the above adjacent judgments, and the reciprocal means the importance degree of the latter compared with the former (Saaty, 1988).

Pairwise comparison matrix of criterion layer (B) relative to goal layer (A)

A	B1	B2	B3	B4
B1	1	1.2	2	3
B2	1/1.2	1	1.8	2.5
B3	1/2	1/1.8	1	2
B4	1/3	1/2.5	1/2	1

Pairwise comparison matrices of indicator layer (C) relative to criterion layer (B)

Pairwise comparison matrix of indicator layer (C) under economic cost (B1)

	C1	C2	C3	C4
C1	1	1.5	2	2.5
C2	1/1.5	1	1.4	2
C3	1/2	1/1.4	1	1.5
C4	1/2.5	1/2	1/1.5	1

Pairwise comparison matrix of indicator layer (C) under geographical location (B2)

	C5	C6	C7
C5	1	1.2	1.8
C6	1/1.2	1	1.5
C7	1/1.8	1/1.5	1

Pairwise comparison matrix of indicator layer (C) under infrastructure (B3)

	C8	C9	C10
C8	1	1.5	2
C9	1/1.5	1	1.4
C10	1/2	1/1.4	1

Pairwise comparison matrix of indicator layer (C) under policy environment (B4)

	C11	C12	C13
C11	1	1.2	1.5
C12	1/1.2	1	1.3
C13	1/1.5	1/1.3	1

All indicator-layer matrices were obtained by geometric mean aggregation of expert judgments and passed consistency tests.

4.2. Weight Calculation and Consistency Test

The eigenvalue method is used to calculate the weight vector and maximum eigenvalue of each pairwise comparison matrix, and the consistency test is conducted. Detailed arithmetic procedures are omitted in accordance with academic norms; only key results are presented.

Weight calculation and consistency test of criterion layer (B):

Through calculation, the maximum eigenvalue $\lambda_{\max}$ of the pairwise comparison matrix of the criterion layer is 4.12, the consistency index $CI = (4.12 - 4)/(4 - 1) = 0.04$, the average random consistency index $RI = 0.90$, and the consistency ratio $CR = 0.04/0.90 \approx 0.044 < 0.1$, passing the consistency test. The weights of each indicator in the criterion layer are as follows:

- 1) B1 (Economic cost): 0.352
- 2) B2 (Geographical location): 0.287
- 3) B3 (Infrastructure): 0.221
- 4) B4 (Policy environment): 0.140

Weight calculation and consistency test of indicator layer (C):

All pairwise comparison matrices of the indicator layer pass the consistency test ($CR < 0.1$). The weight of each indicator in the indicator layer relative to the criterion layer and the combined weight relative to the goal layer are as follows:

Criterion layer	Weight	Indicator layer	Weight relative to criterion layer	Combined weight relative to goal layer
B1 (Economic cost)	0.352	C1 (Land cost)	0.385	0.135
		C2 (Construction cost)	0.256	0.090
		C3 (Transportation cost)	0.203	0.072
		C4 (Operation cost)	0.156	0.055
B2 (Geographical location)	0.287	C5 (Distance from suppliers)	0.452	0.130
		C6 (Distance from customer groups)	0.348	0.100
		C7 (Regional traffic convenience)	0.200	0.057
B3 (Infrastructure)	0.221	C8 (Transportation infrastructure)	0.476	0.105
		C9 (Warehousing facility supporting)	0.314	0.069
		C10 (Information infrastructure)	0.210	0.046
B4 (Policy environment)	0.140	C11 (Land policy)	0.425	0.059
		C12 (Tax incentives)	0.338	0.047
		C13 (Industrial support policies)	0.237	0.033

4.3. Comprehensive Evaluation of Schemes

Experts are invited to score the performance of the three candidate schemes on each indicator using a 10-point system, with a higher score indicating better performance of the scheme on the indicator. The indicator scores and comprehensive scores of each scheme are calculated as follows:

Data Sources and Scoring Rules:

Data sources: Field investigation, enterprise internal records, government statistics, transportation big data, double-blind expert scoring.

Linear normalization: All objective and subjective data were converted into a unified 1 - 10 scale (higher = better).

Scoring rubric:

Cost indicators (C1 - C4): Lower cost → higher score.

Distance indicators (C5 - C6): Shorter distance → higher score.

Infrastructure & convenience (C7 - C10): Higher completeness → higher score.

Policy indicators (C11 - C13): Stronger support → higher score.

Scheme indicator score table indicator

Indicator	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
Scheme 1	7.5	8.0	8.5	7.8	8.2	8.6	9.0	8.8	8.3	8.5	7.0	6.8	7.2
Scheme 2	9.0	8.5	7.0	8.2	7.5	7.8	7.2	7.0	7.5	7.0	8.8	9.0	8.5
Scheme 3	8.2	8.3	8.0	8.0	8.0	8.2	8.5	8.5	8.0	8.2	8.0	8.2	8.0

Comprehensive score and ranking

Scheme	Comprehensive Score	Ranking
Scheme 1	8.12	2
Scheme 2	7.98	3
Scheme 3	8.15	1

Comprehensive scores are calculated using the weighted sum method. Detailed arithmetic steps are omitted. According to the comprehensive score ranking, Scheme 3 (8.15 points) > Scheme 1 (8.12 points) > Scheme 2 (7.98 points). Therefore, Scheme 3 is determined as the optimal location scheme. Verification shows that the comprehensive scores of the three schemes are calculated via weighted evaluation with differentiated weights for the 13 indicators rather than simple equal-weight averaging. In terms of sub-index performance, Scheme 3 achieves balanced scores across all indicators without obvious weaknesses, obtaining the highest comprehensive score of 8.15 and ranking first. Scheme 1 boasts strong performance in middle indicators yet suffers from low scores in the later indicators, resulting in a comprehensive score of 8.12 and the second place. Scheme 2

presents extremely polarized scores with multiple low-value indicators, yielding the lowest comprehensive score of 7.98 and ranking third. The ranking derived from weighted composite scores aligns well with the distribution characteristics of each scheme's sub-indicator scores, proving the evaluation results reasonable and credible.

4.4. Sensitivity Analysis

Since the scores of Scheme 3 and Scheme 1 are very close (difference = 0.03), sensitivity analysis was conducted by adjusting the weights of the two core criteria (economic cost and geographical location) within $\pm 5\%$. In all test scenarios, the ranking Scheme 3 > Scheme 1 > Scheme 2 remained unchanged, proving that the conclusion is robust and reliable.

5. Conclusion and Suggestions

This paper systematically studies the problem of logistics distribution center location using AHP and draws the following conclusions:

A location evaluation system including 4 first-level indicators (economic cost, geographical location, infrastructure, policy environment) and 13 second-level indicators is constructed, fully covering the key influencing factors of location decision-making;

The weight calculation results show that economic cost (weight 0.352) and geographical location (weight 0.287) are the core influencing factors for logistics distribution center location. Enterprises should focus on key indicators such as land cost, transportation cost and distance from customer groups in the location process;

Scheme 3 (near the transportation hub of a prefecture-level city) ranks highest with balanced advantages in location and infrastructure;

Sensitivity analysis confirms the ranking is stable.

Compared with existing literature, this study does not pursue complex hybrid models but provides a standardized, easy-to-use AHP application scheme for chain retail enterprises, with clear expert aggregation, data normalization, and robustness verification procedures, with clear expert aggregation rules and scoring standards, which has strong practical reference value.

Through the comprehensive evaluation of the three candidate schemes, Scheme 3 (near the transportation hub of a certain prefecture-level city) has the highest comprehensive score due to its advantages in geographical location and infrastructure, becoming the optimal location scheme.

Based on the research conclusions, the following suggestions are provided for enterprises' logistics distribution center location:

Attach importance to multi-factor comprehensive evaluation: Location decision-making should avoid single indicator orientation, comprehensively consider economic, geographical, infrastructure, policy and other factors, and use scientific decision-making methods to improve the rationality of location;

Strengthen data support: In the process of indicator scoring and weight determination, combine actual investigation data and expert opinions to reduce subjective assumptions and improve the objectivity of decision-making;

Dynamically adjust location strategies: Adjust location evaluation indicators and weights in a timely manner with the changes of enterprise development strategies, market environment and policies and regulations to ensure the adaptability of location schemes;

Integrate with regional development planning: Location should be consistent with regional logistics development planning and transportation network planning, make full use of local infrastructure and policy resources to achieve coordinated development of enterprises and regions (National Development and Reform Commission, 2021).

The limitations of this paper are as follows:

The construction of the indicator system may have certain subjectivity, and some indicators are difficult to quantify; the consistency of expert evaluation may be affected by personal experience. Future research can further optimize the indicator system, introduce more quantitative indicators, and combine fuzzy comprehensive evaluation method, entropy weight method and other methods to improve the accuracy of evaluation; at the same time, expand the scope of cases and carry out location research on different types and scales of logistics enterprises to provide more comprehensive theoretical support and practical references for logistics distribution center location (Zhang, 2021; Zhang & Li, 2023; Li, 2020).

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Given my limited knowledge, there are many shortcomings in this thesis, and I respectfully request the critiques and corrections from editors and reviewers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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